At a Meeting of the Council of the *Royal Society*, *January* 28. 167$\frac{4}{5}$.

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A

DISCOURSE

OF

Gravity and Gravitation,

GROUNDED ON

EXPERIMENTAL OBSERVATIONS:

Presented to the

Royal Society,

NOVEMBER 12. 1674.

BY

JOHN WALLIS, D.D.

A Member of that *SOCIETY*.

LONDON,

Printed for *John Martyn*, Printer to the *Royal Society*, at the *Bell* in St. *Pauls* Church-yard, 1675.

Fig. 21.

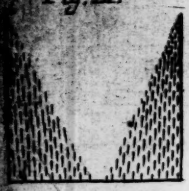


Fig. 22.

Fig 23

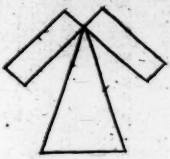


Fig 24

Fig. 25.

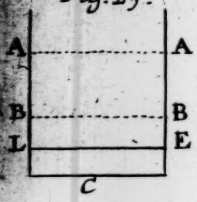
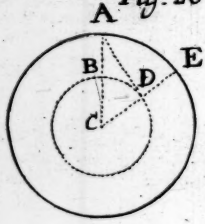


Fig. 26.



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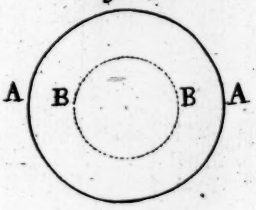


Fig. 28.

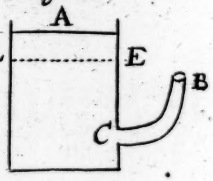


Fig. 29.

Fig. 30.

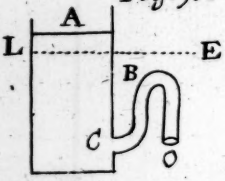


Fig. 31.

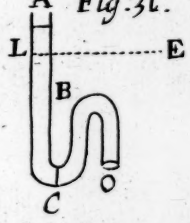


Fig. 32.

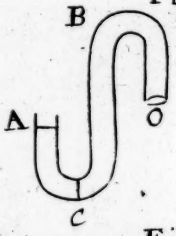


Fig. 33.

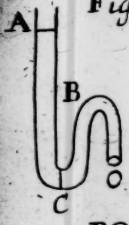


Fig. 34.

Fig. 35.

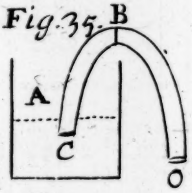
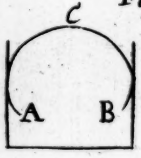


Fig. 36.

Fig. 37.

Fig. 38.

Fig. 39.



A

DISCOURSE

OF

Gravity and Gravitation,

GROUNDED ON

EXPERIMENTAL OBSERVATIONS,

Presented to the

ROYAL SOCIETY,

The 12th of *November*, 1674.

IN Compliance with the Commands of this *Royal Society*, in order to the promoting of Experimental Philosophy, to present you a Philosophical Discourse, either grounded on, or leading to, Experiments; the Subject I have chosen for this Discourse, is that of *Gravity:* the Being and Effects of which, is no otherwise known to us than by Experience, or Discourse grounded thereupon.

The Subject is copious, and therefore I muſt ſingle out ſome few Experiments out of a great many: And they ſhall be the moſt ſimple and unperplexed in their kind, that the Inferences may be the more clear and perſpicuous; and ſuch Experiments onely, as are either commonly known, or have already been made before You, or may eaſily be, whenſoever you pleaſe.

I will not diſpute the Nature of *Gravity* or *Gravitation*, what or whence it is; whether from a Quality within, or a Preſſure from above, or a Magnetick Traction from below: But ſhall take for granted (what every days Experience teſtifies) that there is, (at leaſt in this our Sublunary World) ſuch a thing as *Gravity and Gravitation*; whereby thoſe we call *Heavy* Bodies, have a natural Propenſion to move downwards (towards the Earth, or its Center) if not hindered by ſome more Potent, or at leaſt an Equivalent, Strength.

This Motion downward, we call *Deſcent*; the Endeavour ſo to move, we call *Gravitation*; and the Principle from whence this Endeavour proceeds, we call *Gravity*. And things are ſaid to be more or leſs Heavy, as they have more or leſs of Gravity: Which may be underſtood, either *Extenſively*, according to the Quantity of it; as when we ſay a Pound is heavier than an Ounce, though that be Feathers, and this be Lead: Or *Intenſively*, according to the Degree; as when we ſay, that Lead is heavier than Cork, or Quick-ſilver than Water; that is, gradually heavier, proportionably heavier (bulk for bulk) or (as it is now wont to be called) *Specifically* heavier.

I ſay, the *Endeavour* thus to move, I call *Gravitation*; though by reaſon of ſome Impediment, there be not any *actual* Deſcent. (And it is allowed me, by thoſe from whom in ſome other things I differ, that not onely *Motus*, but *Conatus ad motum*, is properly Gravitation.) Which I thought neceſſary thus to define, that I be not miſunderſtood in

in the ſequel. But I add further, this Endeavour of Deſcent, implies an Averſneſs to Aſcent, with equal force; and that the one and the other are equally the Effects of Gravitation.

This Gravitation, or endeavour to deſcend, is one kind of *Strength*; and may be oppoſed not onely by a contrary Gravitation, but by any oppoſite ſtrength whatſoever; whether by way of *Impediment* onely, or of *contrary Force*. For, though there be divers kinds of Strength; yet they are all thus far Homogeneous, as to be compared each with other, as equal or unequal, greater or leſs, and that in any Proportion.

Thus the Gravitation of the Scale *A* (in *Fig.* 1.) may be oppoſed, or hindered of its Effect, by a contrary Gravitation at *B*, (ſuppoſing all the tackle ſtrong enough;) or by a Force under it, which Thruſts it up; or by a Force above it, which Pulls it up, (or doth at leaſt endeavour ſo to do;) as, for Inſtance, that of a mans Hand. Every of which, being contrary Forces, if equal to that of Gravitation at *A*, will ſtop its Deſcent; if leſs, they will Retard it; if greater, they will force it upwards: Not by making it ceaſe to Gravitate; but by defeating the Effect of that Gravitation.

But it is oppoſed alſo by the Strength and Stiffneſs of the Beam; (for if that either break or bend, *A* deſcends:) And by the Strength, though not the Stiffneſs, of the Strings that hold it, (for if they either break or ſtretch, the weight will deſcend, at leaſt in part;) or by the Hardneſs, Strength, and Solidity of the Floor or Table on which it reſts; which, if ſtrong enough, will ſupport it; or, if the *Medium* be Viſcous, this viſcoſity (which is a degree of ſolidity) will at leaſt retard its Deſcent. All which do oppoſe it, not as contrary Forces, but onely as bare Impediments: Which, if ſtrong enough, do hinder the Deſcent; but, though more than ſo, do not Thruſt it up.

But if the *Medium* be ſuppoſed perfectly Fluid, in every Point, without any averſneſs to ſeparation; it may Hinder, or Retard the Deſcent of *A*, by a contrary Force, or contrary Gravitation, (it ſelf alſo endeavouring a Deſcent by its own Gravity, or at leaſt to preſerve its Station, againſt an Aſcent;) but not as a bare Impediment from its Solidity, Firmneſs, or averſneſs from Separation; which is ſuppoſed to be none. It hath a reſiſtance to Motion, not, to Separation. And of ſuch Heavy Fluides, I intend principally to diſcourſe, and of Solid conſiſtent Bodies, onely with reference unto ſuch.

If it be objected, That there be no ſuch perfectly fluid Bodies; but that thoſe which we call Fluides, are either made up of very fine, but diſunited, Atoms, (each having its own ſhape and figure, though very ſmall) as the *Atomiſts* ſuppoſe; or at leaſt in ſome degree Unctuous and Viſcous: I will not diſpute that point, as not now neceſſary; but only expreſs what it is I mean by Fluid or Liquid Bodies; and the nearer any thing comes to ſuch a condition, the nearer it is to perfect Fluidity. And where ſuch Viſcoſity is very little and undiſcernable, we conſider it as none at all. And even that which is, if it be not ſtronger than the incumbent weight can break, it doth not wholly hinder the Deſcent, but onely retard it: The weight ſinks, though not ſo faſt.

Now, there is in all Heavy Bodies (whether Firm or Fluid) and in every part of them a Propenſity, not onely to a Direct Deſcent, but (if that cannot be obtained) to an Oblique Deſcent, according to any Declivity. (For a River will run down-hill, and ſo will a Bowl alſo; and a ſloping Pole, if not ſupported, will fall obliquely.) Which I the rather note, becauſe I find ſome to put a great ſtreſs on the Lateral Gravitation of Fluides, as peculiar to them; without taking notice, that the ſame is common to Solides alſo: The difference being but this; in Fluides the parts be

be ſeparable, but not in Solides: But the Tendencies are in both the ſame.

Now, of Fluid Bodies it is that I intend principally to ſpeak. Of which the firſt and great Phœnomenon is this, That they will (if undiſturbed) reduce themſelves, by their own weight, to a Level; that is, to an Horizontal Plain, or what as to ſenſe is ſuch; and will ſo continue, if either not preſſed at all, or equally preſſed on all parts.

As if the ſurface, by any means, be Undulous, as *ABAB*, (in *Fig.* 2.) the Prominences at *A*, will ſink to fill up the Cavities at *B*, till all come to the Level of *LE*. And this they will do, *partly* by ſpreading abroad, and flowing into thoſe Cavities as lower places: And *partly* (the whole being fluid) by preſſing down what is under *A*, and preſſing up what is under *B* (in *Fig.* 3.)

For though onely the former of theſe would happen in caſe all under *LE* (in *Fig.* 4.) were a firm Solid ſurface, (like as when water overflows the dry ground, and fills up all the furrows;) and onely the latter, in caſe ſuch Prominences (whether one or more) were contained within Solid Pipes, (in *Fig.* 5.) ſo as that they could not flow laterally into the adjacent Cavities: Yet in the preſent caſe, where both occaſions happen, both Cauſes will operate.

For Nature doth not work by Election, but *ad ultimum virium*, and all the ways it can, where one doth not oppoſe the other. And like as if a Veſſel have two holes, the one at the ſide, the other at the bottom; the water will run out at both: So the Prominences at *A*, being not hindred of either, will partly by lateral Fluxion, partly by direct Depreſſion, fill up the Cavities of *B* (in *Fig.* 5.)

It's true, That a Solid Body, having opportunity of both, becauſe (by reaſon of the coherence of parts) it can move but one way, will move that way only which is moſt Declive: But a fluid Body, being partible in every Point, divides it ſelf every way, as there is opportunity.

Now

Now, ſuch fluid Body being thus reduced to a Level, if undiſturbed, it will ſo remain, (in *Fig.* 6.) For there be now no Prominences, as at *A*, (in *Fig.* 2.) to ſink or flow down; nor Cavities, as at *B*, to receive them: Nor is any part of it more preſſed than other, whereby *that* ſhould ſink, or *this* riſe.

But if at ſome part, as at *D*, (in *Fig.* 7.) by weight or other force, it be preſſed, but not in others; or more at *D*, than at others; it will at *D* ſubſide or be depreſſed, and riſe elſewhere, (in *Fig.* 8.)

And what is thus ſhewed of the Level *LE*, holds equally of any other Level, as *F G.* within the Fluid, at what depth ſoever, (in *Fig.* 8.) If all parts of it be equally preſſed, it keeps its level; but if ſome parts of it be more than others, thoſe will ſubſide, and theſe riſe: becauſe the weaker force muſt give way to the ſtronger.

The like happens in a Syphon inverted, (in *Fig.* 9.) where if the water be higher in the one leg at *A*, than in the other *B*, that will ſink, and this riſe, till they come to a Level at *LE*: And when ſo, it will there reſt, if there be no other force to put it in motion. So in an Ewer, (*Fig.* 10.) or other Veſſel with a noſe; the water in the Veſſel (if higher) will ſink it ſelf, till that in the noſe be raiſed to the ſame height; if that in the noſe be higher, *this* will ſink, and *that* riſe, till they come to a Level at *LE*.

The Reaſon of it (if we do not ſtudy to perplex the Phænomenon) is very evident: Becauſe, while the Fluid (ſuppoſing it uniform) ſtands at the Level *LE*, no part of the ſame Horizontal Plain, at what depth ſoever, is more preſſed than other, whereby it ſhould be inabled to thruſt any other out of place. Upon the ſame account, that of two Scales equally charged, neither can deſcend, or force up the other; but do mutually ſuſtain each other in Equipois, and are at reſt. For though both do *Ponderate*, yet neither

neither doth *Preponderate*. And no Power is able to overbear another Power, unleſs ſtronger than it.

But in caſe the Fluid be higher at *A* than at *B*, the parts under *A* are more preſſed than thoſe under *B*; and therefore thoſe thruſt theſe away. On the ſame account, that if the Scale *A* be heavier charged than *B*, though both preſs downwards; yet the heavier prevails, and forceth up the lighter. For, of contrary Powers, the greater always overpowers the leſſer.

It will yet be not amiſs, (that I may not in the ſequel be miſtaken) to give notice by the way, That what I have ſaid of this Level in Heavy Fluides, is not ſo to be underſtood, as if this Level were in all caſes *Mathematically* exact: For, though it ought ſo to be, if nothing elſe did intervene than what we have hitherto taken into conſideration; yet many times ſome little accidents do diſturb it: As, when a Drop of water, on a dry board, keeps a convex Figure, either becauſe of ſome little Viſcoſity therein, or as ſhunning the contact of that dry ſurface; and Quick-ſilver in a Glaſs-Pipe, or like Veſſel, will have a viſibly convex ſurface, as ſhunning the contact of the Glaſs; and the like would happen in water, if the glaſs were greaſie. And contrary-wiſe, the ſurface of water in ſuch a clean Veſſel would be rather concave; and ſo, I ſuppoſe, would be the ſurface of Quick-ſilver if the Glaſs were guilded within, becauſe of its eaſie application of it ſelf to Gold. It is obſervable alſo, that water in very ſlender Pipes, will riſe viſibly higher than the ſurface of that in the broad Veſſel; becauſe the Air can more conveniently apply its preſſure on that broader Veſſel, than in the ſlender Pipe. And Fluides will many times, upon motion, retain an Undulation, or dancing up and down, ſometimes above, ſometimes below, the true Level, for a conſiderable time before they reſt: Upon a like reaſon, that a *Pendulum* will ſwing back and forth beyond the Perpendicular on either ſide, not by its weight ſimply conſidered,

ſidered, (which would reſt preciſely at the Perpendicular, without riſing on the other ſide,) but by reaſon of its contracted *Impetus*. But theſe and other little inequalities, which are to be accounted for from divers accidents, we here neglect; and conſider onely, what would be the reſult of the Gravity and Fluidity, freed from ſuch other Accidents, too copious here to be inſiſted on. Our meaning therefore is, that (ſetting aſide other Accidents) a Fluid Body, will, by its Gravity, reduce it ſelf to ſuch a Level; and being ſo reduced, will ſo by counterpoiſe preſerve it ſelf, if not diſturbed by other Force.

But it is here objected, That water upon water doth not Gravitate, (and the like of other not-ſpringy Fluides;) becauſe an Element (ſay they) doth not gravitate in its own place. And, for inſtance, they tell us, That a man under water, feels not the weight of the water over him, (in *Fig.* 11.)

Before I directly anſwer this Objection, I have this to ſay to the Principle they alledge: That the intendment thereof at firſt, was no more but this; That the tendency of a heavy Body, being *to* the Earths Center; when there it is, its Heavineſs (if not otherwiſe preſſed) will not endeavour any further motion; (for, to move further, were to move *from* the Center:) And accordingly, if the tendency of any other Body be *to* a certain place, as its term; when there it is, that Principle will not endeavour a motion *from* thence; (for, ſo to do, were to move contrary to its own nature:) And if it be carried further, it muſt be from ſome other cauſe, (as when a *Pendulum* ſwings beyond the Perpendicular, it is not from weight ſimply conſidered, which would there have ſtayed; but from an *Impetus* impreſſed by a precedent motion.) And thus far that Principle is juſt and good. But the Objection perverts it to a ſenſe never intended by the firſt Introducers.

Next,

Next, I would ask; What is meant by the Waters *own Place?* And particularly, Whether water in a Pond, artificially contrived on the top of a Tower, be in its own Place? If ſo, then, though a hole were in the bottom, it ought not to run out. If not in its own place, then the Reaſon fails; for even there a *Diver* ſhall no more feel the weight of the water, than if in the *Thames*. So that it is not its being in its own Place, but ſomewhat elſe, that makes the weight not to be felt.

To avoid this therefore, and the like Inſtances; they now explain their meaning to be, That it doth not Gravitate on any thing which is not ſpecifically lighter than it ſelf. And to this Explication it is that we are to apply our Anſwer.

But neither will this hold. For it is manifeſt (to uſe an ordinary Inſtance) that a Veſſel pierced near the bottom, (in *Fig.*12,13.) will run with a fuller and ſtronger ſtream, than if at the middle, or near the top; and more when it is full, than when half out, or almoſt empty. Which argues a Preſſure of the upper parts upon thoſe near the vent.

And to ſay, they preſs not on the intermediate parts, but onely on the Air without; is a meer evaſion. For the remoter parts of the water cannot preſs that Air, but by preſſing that which is between; like as in a crowd, he that is at a diſtance cannot thruſt him that is at the door, but by thruſting thoſe that are between: And, with a Pole, we cannot thruſt that at the end of it, but by thruſting the Pole: Nor, with a Rope, draw that which is faſtened to it, but by drawing the Rope.

Where yet there is a ſignal difference between *Truſion* and *Traction*. In *Truſion*, it ſufficeth, that the thing be contiguous, though there be no Connexion; but in *Traction* there muſt be a Connexion, and that ſtrong enough; elſe the ſtring will break, and the weight not follow. And though a Heap of Sand will ſuffice to preſs down the Scale; yet a

Rope of Sand will not ſerve to draw it up. And therefore Mr. *Line*'s *Funiculus* (in his Explication of the Torricellian Experiment) muſt have ſomewhat of Texture (as well as Contiguity) to give it ſtrength; without which it will not be able to ſuſtain the weight of the ſuſpended Quick-ſilver. But certainly, if the parts of a Fluid be able to *Draw* one another, much more will they be able to *Thruſt* one another; that is, the one to Gravitate upon the other.

It is therefore much more conceivable (in the inverted Syphon) how the water at *A* (*Fig.* 9.) ſhould thruſt up that at *B*, than how the Air at *E* aſcending, ſhould draw up the water at *B*, and thereby draw down that at *A*. For, in the firſt caſe, there needs only a Contiguity; in the latter, there muſt be a Connexion of all the Parts. And therefore if we ſhould allow, that Mr. *Line*'s *Funiculus*, or Rope of Sands, if granted, would equally ſolve the Phænomenon, by way of *Traction*; yet, ſince the Hypotheſis of *Truſion* (as is acknowledged) will do it alſo; it is much rather to be choſen than that of *Traction*, by a Rope of (Sands, ſhall I call it, or a Rope of) Nothings.

But further, it is confeſſed by a very learned Author, the Author of two Treatiſes; the one intituled, *An Eſſay touching the Gravitation or Non-Gravitation of Fluid Bodies*; the other, *Obſervations touching the Torricellian Experiment*, (who is pleaſed to conceal his Name) that defends the *Funiculus*, and denies our Hypotheſis; that not onely Water, but even Oyl in the Pipe *A*, (*Fig.* 5.) will force up the water at *B*: And if (the Pipe being empty) Oyl were poured on *B*, it would force up water into the Pipe *A*; not to a Level, but to an Equipois; that is, (as his own words are) *to ſuch a proportion of height in the Tube, as will countervail the weight of a like Cylinder of oyl*; and gives the ſame reaſon for it, that we do; *The diſparity of preſſure cauſing Motion or Elevation of the water, in that part not equally preſſed.* So that here, a lighter Body doth Gravitate on a hea-

a Heavier; Oyl, upon Water: And that not onely *ad pondus*, but *ad motum*, as Himſelf admits; that is, (in our Language) it doth not onely *Gravitate*, but *Pregravitate*; not onely Weigh, but Out-weigh.

So that here, the notion of a Fluid not Gravitating on a Heavier than it ſelf, or one as Heavy, is quite deſtroyed.

And it is manifeſt alſo, that not the Level, but the Equipois, is that which is here attended. For the ſurface of the Oyl without the Pipe, becauſe ſpecifically Lighter, will be ſomewhat Higher than that of the Water within it; and juſt ſo much as to make up the Equipois. And, contrary-wiſe, if that in the Pipe were Oyl, and that without it were Water; that within the Pipe would be higher, and in ſuch proportion higher.

The ſame would be, if that at *B* were ſtagnant Quick-ſilver, and that in the Pipe *A* were Oyl or Water, or ſome Lighter Fluid. A pound of Water poured into the Pipe, would it ſelf ſtand higher, (becauſe it would take up more room;) but would raiſe the ſtagnant Quick-ſilver juſt as high, as if a Pound of Quick-ſilver had been poured on; without any reſpect had to the ſpecifick Gravity or Levity.

And a Ship laden, (*Fig.* 8.) will draw juſt as much water, if laden with ſo many hundred weight of Timber, as with ſo many hundred weight of Lead; though that be Lighter, and this Heavier, than a like quantity of Water.

And a piece of Wood (*Fig.* 7.) though Lighter than Water, yet doth not float on the very top, but ſinks ſo far into the Water, till it poſſeſs the place of ſo much Water, as is of equal Weight with it ſelf; that is, till the Horizontal Plain, paſſing by the bottom of the Wood, be in all places Equally preſſed, partly with Wood, partly with Water.

Which being known Experiments, and confeſſed on all

hands, do quite deſtroy the notion of Non-Gravitation of Fluids on what is not ſpecifically Lighter than themſelves. And himſelf grants, (*Eſſay*, p. 14.) that Air in a Bladder, doth Gravitate on Water.

To avoid the Preſſure of theſe Evidences; it is now alledged, That the Oyl or Water in the Pipe *A*, (in *Fig.* 5.) though not intrinſecally Heavier, yet *its Higher Poſition gives it an Accidental weight more than that in the Veſſel*; and hence it comes to paſs, that *That* doth depreſs *This*.

But he doth not conſider, that this doth deſtroy the whole deſign of his ſecond Chapter; which is to prove, That *C doth not Gravitate on D, nor D on E*, in *Fig.* 14; that is, that the Upper parts of the Water do not Gravitate on the Neather. Whereas, if meerly a *Higher Poſition* will make it Gravitate; and that not onely *ad pondus*, but *ad motum* alſo; then muſt the Water be in perpetual Motion, (the Upper parts ſtill preſſing away the Neather, like as, on another account, it happens in Boiling Water; I mean when the Fire is *under* it: for, if it be heated by Fire *above* it, the caſe is much alter'd;) which *perpetual Motion*, the ſaid Author there urgeth as a great Abſurdity. Yet I am not ignorant, that Mr. *Boyle* is indeed of opinion, That in all Fluids the minute parts are in continual motion; (making this the ſpecifick nature of Fluidity, as contradiſtinct to Fixedneſs;) but that is on another account, and concerns not this Point at all. It is not therefore *Safe* for our Antagoniſt, to aſcribe it onely to the *Accidental Weight* of an *Higher Poſition*. Nor is it *Sound* ſo to do. 'Tis true, that a different Poſition may give to the ſame Weight a different Ponderation:

As, for Inſtance; a Weight at *G*, (in *Fig.* 15.) will Ponderate more than at *H*; not, becauſe Higher; but, becauſe, at *G*, it is to deſcend directly; but, at *H*, on an Oblique Plain; which abates its Force, and doth more abate it as it is more Oblique.

And

And a Weight at *reſt* in *F* or *E*, is of leſs Force to move the Balance, than when from *A* it *falls* to *E*; and leſs there than when it is *fallen* to *F*; and even this leſs, than if it had been violently *thrown* down: Becauſe, in the latter caſe, there is a greater contracted *Impetus*.

Again, at *E* or *F*, it will Ponderate more than at *I* or *K*; becauſe thoſe ſuſpended at *A*, are at a greater diſtance from the Center *C*, than thoſe ſuſpended at *D*: The different Poſition, in all theſe, and many other the like caſes, giving to the ſame Weight an Accidental additional Force.

But a *Higher* Poſition, meerly becauſe Higher, gives no ſuch advantage at all: The Weight at *E* being but juſt of the ſame force, as at *F*; and at *I*, as at *K*. For the length or ſhortneſs of the String on which it hangs, doth not at all alter the Weight: As is agreed by all; and Experience teſtifies.

The Reaſon therefore of this Phænomenon is not, becauſe that at *A* in a higher Poſition, is of a greater Weight than a like quantity at *B*: But, becauſe the parts at *C*, (in *Fig.* 5.) are more preſſed than thoſe at *B*; (as bearing the weight of *CA*, which *B* bears not:) whereby *C* is preſſed down, and *B* thereby preſſed up.

BUt, againſt this Explication, he brings an Experiment on wch he lays great weight. *A Porringer filled with Lead, &c. which in the Air, as at* A, *weighed* 78 *ounces*; *weighed in the water about* 68½ *ounces*; *and the ſame Weight it held* (with ſome inconſiderable difference, which he excuſeth) *whether at* C, *the depth of* 40 *or* 25 *inches*; *or at* D, *the depth of but* 12, *or ſcarce* 1 *inch*, (Fig. 16.)

Where he attempts the account of two Phænomena: *Firſt*, Why it weighs leſs in Water than in Air? And *Secondly*, Why it weighs alike at ſeveral depths in Water?

Why it ſhould weigh leſs in Water than in Air, he aſcribes to the *Reſiſtance and Craſſitude* of the Water: And he tells us elſewhere, that, if we ſtrike with our hand the ſurface of Water,

Water, we ſhall find its Reſiſtance not much leſs than if we ſtruck a Board.

By which, if he mean the *Viſcoſity*, or *Reſiſtance to Separation*, he ſpeaks not to the preſent purpoſe: For, as to that, it is to be ſo far conſidered as a Firm Body, not a Fluid, which is that we are now ſpeaking of.

But if he mean, a *Reſiſtance to be diſplaced, and thruſt upward*, to make way for the Porringers deſcent; he ſays juſt the ſame thing with us: For ſuch Reſiſtance is properly Gravitation; and doth countergravitate to that of the Porringer, and take off ſo much of its Prægravitation. Juſt as when the Scale *B*, (*Fig.* 16.) by its Gravitation reſiſts the deſcent of *A*; becauſe *A* cannot Deſcend without the Aſcent of *B*, to which by reaſon of its Gravitation it is averſe. And becauſe the Porringer cannot deſcend but by thruſting up ſo much Water, the Water muſt needs give ſo much reſiſtance to this Deſcent, as it gives to its own Aſcent; that is, ſo much as the weight of the Water that muſt Aſcend; and hath juſt the ſame effect as if ſo much Water were put into the Scale *B*. And juſt ſo much, the Porringer weighs leſs in the Water than in the Air.

And as to what he ſays of the great reſiſtance which the hand finds, when we ſtrike hard on the Water; we are to conſider, not onely the Weight of the Water, but the Swiftneſs requiſite to make way for the Hand moving ſo Faſt: Like as if a Weight of 10 pounds hang in the Air by a Thread; the leaſt touch of the finger will move it, ſlowly: But, to move it 10 times ſo Faſt, will require a force 10 times as ſtrong: And, if you ſtrike it hard with a ſwift ſtroke of the hand; that which made very little reſiſtance to a gentle touch, will conſiderably withſtand the ſtroke of a ſwift hand: Not, becauſe the Weight is 10 times heavier than before, or doth 10 times as much reſiſt Motion; but becauſe it doth 10 times as much reſiſt a Motion 10 times as Swift. Now, ſo much Strength as is requiſite to move ſo much

much Water with ſo much Swiftneſs as is neceſſary to make way for ſo ſwift a Motion of the hand; ſo much reſiſtance muſt the Water give to ſuch a ſtroke, from its own Gravity, without the aſſiſtance of the ſuppoſed Craſſitude or Viſcoſity. But when in the preſent caſe we conſider, how much the Porringer weighs in Water; we conſider onely, whether it Remove ſo much Weight, though never ſo ſlowly; not, with what ſwiftneſs it will remove it; and, as to that, a very little weight more than what it moves will ſuffice.

But his main Objection lyes in the other Point, That the Porringer weighs as heavy at *D*, the depth of 12 or but of 1 inch; as at *C*, the depth of 25 or 40 inches, (*Fig.* 16.)

And juſt ſo, ſay I, it ought to be. For every thing weighs in Water juſt ſo much as its Weight is heavier than ſo much Water. As, for Inſtance, if the Plain ♪♪, (*Fig.* 16.) be in all parts equally preſſed; it is, confeſſedly, the ſame as if not preſſed at all: (for, ſo long, there is no reaſon why one part ſhould riſe, rather than another:) And ſo it would be if *D* were juſt as heavy as ſo much Water. But if *D* be heavier, then is that part of it over-charged, juſt ſo much as *D* is heavier than ſo much Water as would fill the place if this were abſent: And therefore, if not relieved by ſo much Weight in the Scale *B*, it will ſink. And juſt ſo much will ſerve at *C*; that is, it muſt weigh equally, whether at the depth of *C*, or *D*, or any other depth.

But, *ſaith he*, if the incumbent Water do Gravitate on *D*, it will more Gravitate on *C*, becauſe at a greater depth.

True, it doth ſo: But, as the preſſure at *C* is greater than at *D*; ſo is the Counter-preſſure at ♪ more than at ♪; and juſt ſo much more. So that whatever was the Pregravitation at *D*, muſt be the Pregravitation at *C* alſo. (And it is the Pregravitation onely, that is Weighed.) Juſt as when the Scale *A* outweighs *B* by 5 ounces, and into each Scale you

you put 10 Pounds; it will yet outweigh, but juſt 5 ounces, as it did before. So that his Argument from this Experiment, will not hold againſt us.

And the Solution he gives, will hold as little. It is (*ſaith he*) becauſe *the Porringer drives up no more Water out of its Place* at the one Station, than at the other.

But this is a miſtake. For while the Pillar αC, (*Fig.* 16.) to make room for the Porringer, drives away the Water from C to $\varkappa$, that at $\varkappa$ thruſts up all above it as high as α, to make room for it ſelf; as αD doth all that over δ: So that the Water diſplaced, is not the ſame in both. And therefore the Porringer, if not aſſiſted by the incumbent Water, would not equally weigh in different depths; contrary to his own Experiment. Which therefore makes againſt himſelf.

But the great plauſible Objection is, that a Man under Water feels not the weight of it. And why (ſaith he) but becauſe Mans body being heavier than ſo much water, the water doth not Gravitate on it.

But this Reaſon is (as the Schools ſpeak) *non cauſa pro cauſa.*

If the Queſtion were, Why the water doth not *Raiſe* the Body, (as it would do ſo much Wood;) the Reaſon had been good; Becauſe ſo much water doth not preſs downward more than the Body doth; and therefore is not able to preſs it away.

But when the Queſtion is, Why a man doth not *Feel* it; that is, Why he is not Hurt by it, or put to Pain; the Anſwer, Becauſe ſpecifically Lighter, will not ſerve. For,

1. A Man, by this Reaſon, ſhould not feel the weight of Wood, becauſe proportionably lighter than himſelf: Yet we find a Man will as much ſink under a Load of Wood, as a Load of Lead, if of equal Weight. And if it be ſaid, This is, becauſe, though the Man be not, yet the Air about him

him, is Lighter than that Wood: I ſay, it is ſo; but this ſhould therefore cauſe onely a Lateral Preſſure on that Air, not a Direct Preſſure on the Man. And, though a Man ſtood up to the neck in Water, he ſhould yet find the burden of the Wood laid on his ſhoulder; notwithſtanding that both the Man, and all about him, be Proportionably heavier than Wood. And he ſhall equally feel it, as if it were an equal Weight of Lead, if both be above the Water. So that the circumjacent Air, is not that which makes the Wood weigh upon the Man.

2. Though the whole Man be Heavier than ſo much Water; yet many Parts of him are Lighter; and would, of themſelves, ſwim in Water, (though, by their Connexion with ſome Heavier, they be made to ſink; like Wood tyed to a piece of Lead:) Now all theſe Parts, at leaſt, ought to feel Pain, if the ſpecifick Gravity were the onely cauſe of Indolency: But do not.

3. A Man immerſed in Quick-ſilver, which is a Heavier Fluid, though he would thereby be boyed up, yet would he no more feel the incumbent Weight, than a like weight of Water. And, though the Experiment cannot ſo conveniently be made in Quick-ſilver as in Water; yet as to part it may be made, by thruſting the Hand into Quick-ſilver, which ſhall no more be preſſed by it, than if thruſt into an Equivalent depth of Water; that is, about 14 times as deep. And Flyes, or other ſmall Animals, immerſed in Quick-ſilver, are not thereby preſſed to death, but do ſafely emerge to the Top. So that it is but a Fanſie to think, that onely the Proportional or Specifick Lightneſs of the Water, is the cauſe of that Indolence, ſince Liquids Proportionably heavier, if not Poſitively heavier, will be felt as little.

4. Let us ſuppoſe an inverted Syphon, (*Fig.* 17.) filled from *A* to *B* with Quick-ſilver; from thence to *C* with Water, ſo high as to ballance the Quick-ſilver at *A*. If

now Oyl (which is Lighter than either) be poured on *A*; I ask, Whether the Quick-ſilver at *A* will not be thereby depreſſed, and that at *B* and *C* raiſed? Certainly it will. But why? The Oyl cannot (by *their* Principles) Gravitate on *AB*, becauſe this is Quick-ſilver: Nor yet (as *they* ſpeak) mediately upon *BC*, for even this is Water, and therefore heavier than Oyl: No, nor on the Air above *C*; for the Oyl at *DA* is already lower than it, and therefore cannot affect to poſſeſs its place. It ſhould therefore, by *their* Principles, not gravitate at all, ſince there is nothing below it lighter than it ſelf, on which it ſhould gravitate: Yet gravitate (we ſee) it will, and thruſt out of place that whole Body *ABC*; notwithſtanding (if that be conſiderable) the higher Poſition of *C*, and its greater Specifick Heavineſs. And all this while the Animal in *BC* ſhall remain unhurt, notwithſtanding there be not onely *Gravitatio ad Pondus*, but *Gravitatio ad Motum* too.

So that the notion of Non-Gravitation on a Fluid not ſpecifically Lighter than it ſelf, is quite out of doors.

And the truth is, ſuppoſing *ABC* to be in Equipoiſe, the ſuperfuſion of *AD* will equally depreſs *A*, whatever the Liquor be, if the Weight be equal. An Ounce weight, will ſtill be an Ounce weight; and an Ounce weight will juſt ſo much depreſs the Quick-ſilver, whether it be an Ounce of Wine, Water, Oyl, or Quick-ſilver; (that is, juſt ſo much as to thruſt half that Weight, out of the Leg *AF*, *Fig.*17. into the Leg *FC*;) without any regard had to the ſpecifick Gravity or Levity of the Liquor *AD*, which, as to this Point, is of no conſideration at all. And if the higher Poſition of *D* above *A* be thought of moment; the higher Poſition of *C* above both muſt be ſo too. And there will be nothing ſteady to fix upon, but, that the Poſitive Weight of *DF* being (at leaſt in Proportion to the bigneſs of the Pipe) more than that of *FC*; *that* will thruſt *this* away, till they come to an Equipoiſe.

It's

It's true, that, if the ſpecifick Gravity of the Liquor *AD*, were greater than that of the Quick-ſilver in *AB*; there would, upon another account, have been ſome difference: Becauſe then, the Heavier Liquor being upmoſt, it would not onely *preſs upon*, but *preſs into*, the Body of the Lighter; and they would by little and little ſhift places; (as when Water is poured upon Wine, *that* will by little and little ſink to the bottom, and *this* riſe:) Becauſe, by ſuch Deſcent, each Particle thruſts up a Lighter Body than it ſelf. But, if the Upper be Lighter; though it preſs *on* the Heavier, it cannot preſs *into* the Heavier, without thruſting up a Heavier Body than it ſelf. And this, I ſuppoſe, if they will conſider their own Notion, is that they mean, when they ſay, A Lighter Body doth not gravitate on a Heavier.

And if ſo much Oyl were poured on *A*, as to thruſt the Quick-ſilver beyond *F*; ſome of that Oyl would paſs by it, into the other Leg, as high as *C*.

And, in ſuch Caſes as theſe, the ſpecifick Gravity or Levity is conſiderable: But not as to the Caſe in hand; where an Ounce of Oyl poured on *A*, ſhall depreſs it juſt as much as an Ounce of Quick-ſilver would do; and thruſt up *C* juſt as High.

Beſide this, (of Non-Gravitation on a Heavier Body;) the ſame Learned Author hath two Expedients for ſalving the Indolence of a Man under Water, or his not feeling Pain by the Weight of it.

The *Firſt* is this: Suppoſing a Brick-work, as in *Fig.* 18. but without Mortar; if ſome few Bricks were taken out of the bottom, there would not hereupon ſink a Pillar of that Baſe, but onely a Kind of Pyramid; the reſt being, in manner of an Arch, mutually ſupported. And thence he ſuppoſeth, that thoſe middle Bricks did not bear the Weight of a Column, but onely of a Pyramid. Which Pyramid if taken away, the reſt would not gravitate upon that Ca-

vity. And in like manner he ſuppoſeth it muſt be, if, for Bricks, were Grains of Wheat; yea, of Sand; and, conſequently, of leſſer Particles; and, even thoſe of Water; which he ſuppoſeth would thus ſupport each other, without gravitating on thoſe under them.

But he proceeds upon ſeveral miſtakes.

. Firſt, he ſuppoſeth, That, becauſe thoſe middle Bricks being taken away the reſt do not fall; therefore, when they were there, they bore nothing of that Weight. Which is juſt as if he ſhould argue, Becauſe, when a Beam (in *Fig.* 19.) is ſupported by three Poſts, if the middle Poſt be removed, it will not fall; therefore, while it was there, it did bear nothing of the Beams Weight: Or, Becauſe a Table, (in *Fig.* 20.) ſupported by five or ſix Legs, will ſtand, though any one of them be taken away; therefore that Leg did bear nothing: And conſequently, (becauſe that Leg is any Leg) therefore none of them did bear any Weight: Whereas, while all were there, each did bear its part, and thereby eaſe the reſt; which, in the abſence of one, muſt now bear the more. And if the whole ſpace under it were filled up with ſuch Supports, (or, which would be Equivalent, an intire Body of that breadth,) each would bear (without any conſiderable difference) juſt ſo much as what is juſt over it. And ſuch is the eaſe of Fluids. Onely this I add, That if one of the Legs ſhould be too weak to bear its Proportional part, yet if the reſt be as much more than able to bear theirs; that weak one will not break, being relieved by the reſt.

Secondly, Admitting that in Brick-work it would ſo be; yet it is onely upon this account, Becauſe thoſe parts of the Bricks which hang over, are coherent with the parts ſupported, and cannot fall without breaking the Brick: But, if they were as eaſily ſeparable part from part, as Brick from Brick, (which is the caſe of Fluids;) thoſe parts would fall, as well as the middle Bricks: And conſequently, not a Pyramid, but a Column, or rather more. Again

Again, Thirdly, Whereas he argues, from Bricks to Grains of Wheat, and from thence, to Sands, &c; The Conſequence will not hold. For the ſhorter his Bricks are, the leſs will hang over in each Layer. As if now, for Inſtance, each Brick lye two Inches over; if the Bricks were but half ſo long, each would lye over but one Inch; and conſequently (ſuppoſing their thickneſs the ſame,) the Pyramid on that Baſe would be twice as great (becauſe twice as tall;) and ſtill, as the over-hangings decreaſe, that Pyramid increaſeth; till at length, when thoſe over-hangings come to nothing (which is the caſe of Fluids,) the Pyramid becomes a Column, or even more than ſo. And if, in a Heap of Wheat, *Fig.* 21. (as here in a Pile of Bricks,) he remove ſo much of the bottom; he will find, that inſtead of a Pyramid on that Baſe, there will fall down more than a Column (part of an inverted Pyramid:) And the more ſuch Heaps approach to the nature of Fluids; the more will it be ſo. So that, by this Argument (if there were not another Expedient, of which I ſhall ſpeak by and by,) the lower parts muſt bear, not leſs, but more, than the Column incumbent on them. And, if he found it otherwiſe in a Tube filled with moiſt *Calice*-Sand; this was not, becauſe *that* above did not gravitate; but becauſe it was ſo wedged in, that it could not fall. Which, in perfect Fluids, we are not to ſuppoſe.

Laſtly, He doth, by this Explication, deſtroy his own *Hypotheſis*. For he grants, in a Pail of Water (for *Inſtance*,) that all the Parts, as well upper as lower, do gravitate on the Bottom, though not each on other: Whereas, if thoſe upper Parts be ſo ſupported (as in his Brick-Arch) as not to Gravitate *on* the Cavity; much leſs will they gravitate on the Bottom, *under* that Cavity. And if, as he ſuppoſeth, a great Heap of Wheat would not break an empty Egg-ſhell; it is not, becauſe the Wheat wants Weight, or Gravitation; but becauſe the Grains are ſo intangled as not

to

to fall right down, (like as in a heap of Buſhes, one would bear up another, though all do gravitate:) But in Liquids it is otherwiſe; which we ſuppoſe partible in every Point.

But however, this of the Egg-ſhell happen to prove; it ſerves not his *Hypotheſis* at all. For, the Air in the Egg-ſhell, being Lighter than the Wheat that lyes on it; this ought to gravitate (by his own Principles,) and to break the Egg-ſhell. If, by Arch-work, the Egg-ſhell be defended; this is not for want of Gravitation; but becauſe that Gravitation is ſurmounted by a greater Strength. Like as when a great Weight hangs on a ſtrong Tack; or a heavy Scale, ſupported by as great a Weight in the other, or by a ſupport underneath; and a thouſand other the like Accidents.

His *other* Expedient is, from the Lateral Preſſure which he ſuppoſeth all Fluids to have; whereby he ſuppoſeth the Perpendicular Preſſure to be abated.

But here he proceeds upon a miſtake alſo. For, though it be very true, that Water will flow upon a Declivity; yet not as Fluid, but as Heavy. For we ſee a Bowl runs down a Hill, though not a Fluid, but a Solid, Body. And a broad Solid, lying on a narrow Pillar, (in *Fig.* 22.) hath in every part a Lateral Preſſure as well as Water; and, if it be cut in the middeſt, will fall off on either ſide, as Water would do. And, when it doth not; the reaſon is not a want of Propenſion, but becauſe this *Lateral* Propenſion is checked or impeded by a Greater ſtrength of Coheſion; like as its *Perpendicular* Propenſion is checked by that greater ſtrength of the Pillar. And like as the Pillar, if too weak, will break under the Perpendicular Weight; ſo, if the ſtrength of Coheſion be leſs than its Lateral Propenſion, the Solid will divide as a Fluid would do. As when a Solid breaks by its own Weight, (in *Fig.* 23.)

On the contrary; Water in a Pail (or other Veſſel,) though

though a Fluid, hath its Lateral Propenſion *Reſtrained* by the ſides of the Veſſel (as by a greater ſtrength,) but doth not *Loſe* it; and, if the ſides chance not to be ſtrong enough, will break through; doth at leaſt endeavour it, though they be ſtrong enough.

So that, both in Solids and Fluids, each Particle hath its Lateral Propenſion, as well as Perpendicular; though it be ſometimes reſtrained, or over-powered; *there*, by the Coheſion of Parts; *here*, by the Strength of the Sides: but (in both Caſes) if thoſe Strengths be too weak, that Propenſion prevails.

Now, as this Lateral Propenſion of Fluids, is kept in by the Sides of the Veſſel, as to the utmoſt parts of it; ſo, as to the inner parts of it, they keep in each other. The Lateral Preſſure of *A*, (*Fig.* 24.) is ſuſtained by that of *B*; and this by that; not as by Greater, but as by Equal Strengths. For *A* cannot thruſt away *B*, without thruſting up a Body as Heavy as it ſelf; nor *B* thruſt away *A*.

So that, the Lateral Preſſure of the Parts being mutually ſuſtained each by other, and the Perpendicular Preſſure by the Parts under it; hence it comes to paſs, that thoſe under-parts bear onely the Preſſure of a Column, and no more; (which is the Expedient that I intimated but now.) And therefore, in the Heap of Wheat, but now mentioned, though, upon an aperture in the Bottom, more fall down than ſuch a Pillar, (becauſe, when that is gone, the Lateral Preſſure of the reſt doth operate,) yet, while that Pillar was there, that part of the Bottom did bear no more but it.

But if theſe Expedients of his do not ſerve; What is the Reaſon (you will ask) that the Man under Water, feels not the Weight of it?

I would Anſwer, Firſt, That it is not agreed, that, at a great depth, a Man ſhall feel no Pain at all. And I hear, that

that Mr. *Gratrix* having contrived a way of taking breath, at a great depth under Water, through long Pipes reaching to the top of it; yet found his breaſt there ſo compreſſed by the water, that he could not draw breath. But, in ſmall depths of water, I do not deny but that a Man may remain for ſome time without any conſiderable Pain.

The Reaſon, I judge, is this; Becauſe the man incompaſſed by a Fluid, (whether ſpecifically Heavier or Lighter than himſelf, it makes no matter,) is equally preſſed on all ſides; and thereby ſuffers no luxation of Parts; and, conſequently, no ſenſe of Pain. But upon the luxation or laceration of any part, eſpecially a Nervous part, Pain ariſeth. Hence it is, that our Fleſh feels not the hardneſs of our Bones, becauſe ſo fitted thereunto as to ſuffer no luxation or laceration by it: But, if the Bone be broken or diſlocated, we ſhall then find it to hurt us; and feel it hard and ſharp.

And though the Body, by ſuch compreſſion, may be contracted into a leſs room, by reaſon of the Air, Blood, and other ſpringy Liquids; yet theſe being all uniformly preſſed, without any tearing of the Nervous parts, he ſuffers nothing of Pain from it.

And hence it is, that the Egg-ſhell, (but now mentioned,) though preſſed by a Body ſpecifically Heavier than it ſelf, (by which therefore, according to *their* Principles, it ought to be cruſhed,) receives no prejudice, becauſe equally preſſed on all ſides: Which it doth the more eaſily ſuſtain by reaſon of its round form, in the nature of a continued Arch. And we find, in experience, that a Round Glaſs, though but of equal thickneſs, will bear a much greater Preſſure from without, than from within; and more than if it were flat-ſided; and more, if the Preſſure be of all ſides, than if but in ſome onely. All which concur in the Egg-ſhell ſo ſituated: But if preſſed onely upon one ſide, a leſs Preſſure would break it.

I add

I add alſo, That though in perfect Fluids there be no ſuch Arching; yet in a Heap of Solids (as that of *Wheat*) ſomething there is of that nature; and the more, as thoſe Grains be bigger, and conveniently ſhaped; and may therefore help to bear the burden: Like as 4 or 5 Legs, in the Table we mentioned, if ſtrong enough, will ſupply the defect of one weak one; which therefore is not broken, though not ſtrong enough of it ſelf to bear its part. But the more any ſuch Heap approacheth to the nature of a Fluid, the leſs is there room for ſuch Arching; and, in perfect Fluids, none at all.

Hence it is alſo, that a Spunge, though Lighter than Water, and Flaccid alſo, will not yet (though faſtened to the bottom of a Veſſel) be cruſhed together by the Weight of the incumbent Water; Becauſe the Water *within* its Pores doth bear out the ſides with as great a ſtrength, as that *without* would preſs them in. And the like we ſee, when the Lungs, taken out of Animals, are immerſed in Water.

And the ſame account ſerves, for the preſſure of Air on Animals. The Air within, preſſing as ſtrongly outward (by its Spring,) as that without, preſſeth inward; there is no hurt to the Animal at all. And, contrary-wiſe, the preſſure of the Air into the Mouth and Throat, doth not break open his Breſt or Belly, becauſe ballanced with as great a Preſſure without.

But if a Hand or Arm, be put into the Air-Pump, and the Air about it pumped out, that there be a failure of the outward Compreſſion to ballance that within the Arm; the Spring of that within it, will put the Arm to a great torture, (as divers of this *Society* have found by experience.) And many Animals, by that means, have been killed within the ſame Pneumatick Engine, in a much ſhorter time, than would have been for want of Reſpiration onely.

The like is ſeen in the breaking of Glaſs Bubbles hermetically ſealed, and of Lambs Bladders, in the ſame Pneu-

matick Engine; upon the Subtraction of the Ambient Air; as alſo the boiling of warm Water, and the ſtrange expanſion of Blood into Bubbles, upon ſuch Subtraction of Air; and many the like Experiments, made by Mr. *Boyle* (an Honourable Member of this *Society*) in that Pneumatick Engine of his Invention.

But while I name theſe, I do anticipate what I am next to handle; which is the Compreſſion of *Springy* Bodies.

WE have been hitherto diſcourſing of ſuch Fluids principally as Water is ſuppoſed to be; that is, Fluids uncapable of Compreſſion, becauſe not Elaſtical or Springy.

But Springy Fluids, ſuch as we ſuppoſe the Air to be, may by an incumbent Weight, not onely ſuffer a Truſion (as Water may) into another Place, (as from *A* to *B* and *E*, in an open Pipe, in *Fig.* 17:) but a Compreſſion, into a leſs place. As for Inſtance, if the Pipe be cloſe ſtopped at *C*, (or Hermetically ſealed,) ſo as *AB* be Water, and *BC* Air, or other Springy Fluid; a ſuperfuſion or addition of the Weight *AD* (whether Fluid or Solid,) will raiſe *B* to *E*, and contract the Air *BC* into the ſpace *EC*; that is, ſo much as till the Spring in *CB*, (which was a Strength equivalent to the Preſſure of *AB*,) becomes (by this Contraction) equivalent to the Preſſure of *DB*. And if more yet be ſuperfuſed on *D*, *CE* will be yet more contracted, and ſo onwards; the ſtrength of the Spring being ſtill made equivalent to the preſſure of the Weight. For, while the Spring *CB* is too weak; the Weight (being a greater ſtrength) will thruſt it cloſer: And, if *CE* be too ſtrong, it will (as a greater ſtrength) thruſt away that Preſſure: And can never reſt, but when the ſtrength of the Spring is juſt equivalent to the Preſſure.

So in Solids: If (for Inſtance) a Room or Veſſel be filled with Wool as high as *BB*, (*Fig.* 25.) and more Wool or other Weight (whether Heavier or Lighter than Wool) be

be laid on, as to *AA*; the Wool ſhall be depreſſed to *LE*; and more yet, if more Weight be laid on.

And in like manner, if *BCB* be Air, and this preſſed, either by the incumbent Air *AB* (ſuppoſing Air to be heavy,) or by a Solid Weight or Force, ſo cloſe on all ſides, as that the Air cannot paſs by or through it.

And, this being granted; the Torricellian Experiment (with others of the ſame nature) is, confeſſedly, ſolved by the Preſſure of the Air; which was anciently thought to be by a *Fuga vacui*. For, if the Air be heavy, it muſt Gravitate; that is, endeavour a Deſcent (as other Heavy Bodies do,) and actually Effect it, if not oppoſed by at leaſt as great a ſtrength. And the Spring of the Air (allowing it to have a Spring) muſt always be of ſuch a Texture, as is equivalent to the Weight or Force which it bears.

Now, as to the Weight of Air, or its Poſitive Gravity, the *Peripatetick* Philoſophy doth not acknowledge it; but takes it to be Poſitively Light, and conſequently to endeavour an Aſcent. And ſome others ſay the ſame, not onely as to Air, but as to all Heavy Bodies. And whereas we ſuppoſe in them a Poſitive Gravity; and that what we call Levity is but comparatively ſo, being onely Gravity in a leſs degree; they take Levity to be Poſitive, and Gravity to be but a leſs Degree of Levity; and, conſequently, thoſe Heavy Bodies, not to Affect a Deſcent, but to be Thruſt down by Bodies more Light, which more ſtrongly affect a Higher Place.

But againſt theſe (the one and the other) I apprehend (as to Philoſophy) theſe Inconveniences; which, to me, ſeem cogent Arguments.

If this Motion up-ward be natural; it muſt be either an Averſneſs from the Center, as the *Terminus à quo*; or a Propenſion to ſome other Place, as the *Terminus ad quem*.

If they ſay the Former; it is true, that then *B* ought to

move from *C*, in Perpendicular Lines, as *CBA*, (*Fig.* 26;) and the Phænomenon doth not contradict it. But if the first intendment of nature be, not to be here; without any Positive tendency, where to be; it seems much more intelligible, that somewhat should Thrust it thence, (by somewhat more forcibly pressing between,) than that it should Fly thence, without Affectation of any other Place.

But if they say, (as seems more rational, if Levity be the Positive Principle,) that it is an Affectation of some Higher Place, suppose *A*: While *B* is just between *C* and *A*, the motion ('tis true) would be in the Perpendicular *CBA*, (as the streighteſt way thither:) But if it were any where else, as at *D*; then its motion to *A* would not be in *DCE* the Perpendicular, but in *DA* an oblique line. Which is contrary to all Experience: For the same Light body, whereever it be, moves upward in a Perpendicular; as well as a Heavy body, in a Perpendicular downward.

And if, to avoid this, they would say, That it moves not to a certain place, as *A* or *E*, determinately; but to that place, whatever it be, that is just over it: I say, this is not properly the moving *To* a place, (if it be indifferent whether to *A* or to *E*;) but rather a moving *From* a place; that is, to be as far from *C* as it can: Which is the former branch of the Supposition, and against which we did before urge the former inconvenience. Which makes it not likely, that there is any such thing as *Positive* Lightness at all; since it will be hard to assign, what shall be the *Terminus ad quem*, which such a Mover aims at.

But waving this Argument from Philosophy at large; I shall argue from Experiment, (as to the Air,) thus:

Suppose we Air in the Bladder *AA*, (*Fig.* 27.) of the same Tensure with the External Air; and therefore such as will not (as *they* speak) Gravitate, or (as *I* would rather say) Prægravitate thereon; nor yet Prælevitate; (being of the same specifical Gravity or Levity with it:) If this be com-

compreſſed into a leſs room, as *BB*; it will then retain the ſame Quantity of Gravity or Levity as before, (ſince all that Air is ſtill here, with all its poſitive Quality:) But (becauſe now within leſs Dimenſions) it will be Gradually, or (as now the Language is) Specifically, more than before, Heavier or Lighter, according as that Poſitive Quality was Gravity or Levity. (For, as the ſame quantity of Heat, in leſſer ſpace, makes the ſubject Intenſively Hotter; ſo the ſame quantity of Heavineſs, in a leſs Room, makes it Intenſively Heavier; and, of Lightneſs, Lighter.) But experience teſtifies (as is confeſſed) that compreſſed Air is Intenſively Heavier, or (as we now ſpeak) Specifically Heavier, (and on the Ballance is found ſo to be;) not Lighter, than before. Therefore its Poſitive Quality was Heavineſs, not Lightneſs.

The Poſitive Gravity of the Air being thus evinced; and, conſequently, that the Air Aſcends, onely becauſe it is Thruſt up by Bodies more Heavy; (like as Water riſeth upon the caſting in of Earth, or other Heavier Bodies;) the Torricellian Experiment, with other the like Phænomena, are eaſily ſolved from Statical Principles, without having recourſe to a *Fuga vacui.*

For, admitting (as before) that (in a Veſſel with a Noſe, or a Syphon inverted, *Fig.* 28, 29.) the Fluid at *A*, by ſinking it ſelf, will raiſe that at *B*, to the Level *LE*; then, in caſe the Noſe at *B* be not ſo high, the Liquor (if not otherwiſe ſtopped) muſt needs run over. And, if any ſhould ſay, the Reaſon hereof is, Becauſe the Air at *B* flies away (by its Levity) and the Water follows to avoid a Vacuity; he would hardly be aſſented to by thoſe, who ſee a viſible Weight or Force at *A*, to over-preſs it, and thruſt it out.

And, for the ſame Reaſon, if the Noſe or Pipe, before it comes to the height of *E*, be recurvate, (*Fig.* 30, 31.) and turned down to *O*; that which would have run over at *B*, will now run out at *O*; being thruſt up to *B*, by the Weight of

of *A*, and falling down from thence, by its own Weight.

But in case *A* be lower than *B*, *Fig.* 32. (and the Fluid uniformly Heavy;) *A* will not be able to drive it up to *B*, much less make it there run over, or turn about to *O*: But, contrary-wise, if it were full to *B*, this would præponderate, and raise that at *A*.

Yet, if *AC* were a heavier Fluid, suppose Quick-silver; & *CB* a lighter, as Wine or Water; the Effect would follow as before; till the greater Height of *CB*, do countervail the greater Heaviness of *AC*.

And, contrary-wise, if *AC* be specifically lighter than *CB*, (*Fig.* 33.) suppose *that* Water, and *this* Quick-silver; then must that be in such proportion Higher than this, or else it will not rise to *B*, nor run out at *O*. But, if *AC* be higher than in such proportion; the Effect will follow, from the Prægravitation of *A*, without having recourse to a *Fuga vacui*.

And thus far the Ancients would agree with us. For they never flye to a *Fuga vacui*, so long as there is a visible Weight or Force to Thrust up the Fluid.

BUt that which gave occasion to introduce this Notion of *Fuga vacui*, were but these Two Experiments, (and such as are reducible thereunto;) wherein, for want of a Force to raise Liquids by way of *Trusion*, they had recourse to this of Traction, *ne detur vacuum*.

The first that of *Suction*, in Pumps, Syringes, and other the like occasions. The other is that of a *Syphon*, whereby Liquors are carried over considerable heights above their Level.

For if the nose of a Syringe be immersed in Water, as at *B*, (*Fig.* 34.) and the handle or *Embolus* be drawn back; the Water or other Fluid will follow it, from *B* into *D*: Which being contrary to the nature of a Heavy Body, and no other Force appearing to thrust it up; it was imagined, that Nature abhorred a *Vacuum*, and this made the Liquor rise contrary to its particular Propension. To which *Fuga vacui*

vacui (as it was wont to be called,) *Linus* of late (and ſome others after him) have given the name *Funiculus*. And the like is to be ſaid of all ſorts of Pumps, and other the like Engines, which draw Water by way of Suction.

And as to the Syphon; If the End *C* be immerſed in Water, or other Liquor, (*Fig.* 35.) though *B*, the top of the Syphon, be much higher than *A*, the ſurface of the Liquor; yet, if *O* be lower than *A*, though it will not of it ſelf begin to run; yet, if by Suction or otherwiſe, it be ſet a running, this Current will continue, till either *A* be ſunk ſo low as to let in Air at *C*, or be lower than the outward Orifice *O*. The reaſon whereof, ſay they, (ſince there appears not any Force to thruſt it up,) muſt needs be this; *BO* flowing out by its own Weight, if *CB* did not follow it (contrary to the Propenſion of its own Gravity,) a *Vacuum* muſt needs enſue; which therefore, they ſuppoſe, Nature doth abhor.

For Anſwer, I ſay, *Firſt*, There being no other Foundation in Nature to prove this Abhorrence, but onely theſe Experiments; and this not otherwiſe known, but being onely invented as an Expedient to ſerve a turn: If we can otherwiſe ſolve the Phænomenon, and ſhew a Force which they did not think of; there will be no need of this Expedient at all. And this Abhorrence muſt be either *gratis dictum*, without any cogent proof; or ſome other evidence muſt be ſhewed for it; than thoſe who did introduce it were aware of. For all the ſubſidiary proofs of late invented, were not the grounds of introducing the opinion. And therefore, without diſputing, whether Nature can or cannot admit a *Vacuum*; I ſhall onely ſhew, That there is no need of that Notion as to this buſineſs.

Next; That this *Fuga vacui* is not the cauſe of Water thus riſing in a Pump or Syphon, I thus argue. For, if ſo, it ought to hold to any height whatever. A Pump (for Inſtance) muſt draw Water an hundred foot high; and a Syphon convey Water over the higheſt Hills or Towers. For, the

the Argument equally holds, whether the height of *B*, be two Foot, or two hundred Foot; if *BO* flow out, and *CB* not follow, a *Vacuum* muſt inſue equally in either caſe.

And the Conſequence of this Argument is ſo clear, that, in confidence thereof, the Ancients did not doubt but that it would be ſo. None (that we know of,) till *Galilæo*'s time, having ever queſtioned it; or aſſigned any determinate height beyond which a Pump would not draw water, or over which a Syphon would not convey it. And it was a ſurpriſing diſcovery, and wholly unexpected, when (about the end of the laſt Century) it was firſt found out by experience, that Water could not thus be drawn higher than about 34 Foot. I ſay, *about* 34 Foot (not juſt ſo much) becauſe that alters with the temperature of the Air. When the Air is very light, it will not much exceed 32 Foot; when very heavy, it may reach 35 Foot.

Which Experiment alone did evidently evince, that the ſuppoſed *Fuga vacui*, was not of an Infinite, but of a Determinate, ſtrength. Which put *Galilæo* upon the inquiry, Whether it were not from ſome other cauſe than *Fuga vacui*, that it would be drawn ſo high, but not higher. And he happily lighted on this Hypotheſis, of the Counter-gravitation of the incumbent Air.

The ſame hath been ſince improved by *Torricellio* (and others after him,) who rationally argued, that if ſuch Counter-gravitation of the Air, would countervail the Weight of 34 Foot of Water; it ought in lighter Liquors countervail a greater height; and a leſs height in Heavier. And found, upon Experiment, that ſo it was: (If ſome little difference chance to be ſometime diſcovered; it is to be accounted for, from ſome different conſtitution of the Air about us, or other little accidents, too many to be here recounted:) And particularly, that, as Water would be ſo raiſed about 34 Foot; ſo Quickſilver, to the height of about 29 inches and no more: (I mean 28, 29, or 30, as the Airs temperature doth vary.) Which agrees with the proportion of

of the ſpecifick weight of thoſe Liquids. (Quick-ſilver being near upon 14 times as heavy as Water.) And, from him, the *Torricellian Experiment* takes its name.

The Experiment is thus adminiſtred, (in *Fig.* 36.) A Glaſs-Pipe cloſed at the bottom, being filled with Quick-ſilver, and then inverted; the orifice being ſtopped (with the finger or otherwiſe) till it be immerſed in a Veſſel of ſtagnant Quick-ſilver, and then opened; If the height of the Pipe (above the ſtagnant Quick-ſilver) be not more than 29 inches, or thereabouts, it will remain full.

The cauſe hereof, *ſay they*, is, *Ne detur Vacuum*: For if the Quick-ſilver ſhould ſink, there being no way for the Air to enter, there would enſue a *Vacuum*, which nature abhors.

The cauſe, *ſay we*, is, Becauſe the weight of the incumbent Air on *A*, (which we have already proved to be Heavy,) is equivalent to the weight of 29 inches of Quick-ſilver: Which therefore, being defended by the cloſed Glaſs (which we ſuppoſe otherwiſe to be held firm,) from any other Preſſure than its own Weight, is by that Counter-preſſure ſuſtained.

But further: If the height of the Pipe above the ſtagnant Quick-ſilver be more than about 29 inches; that in the Pipe will ſink to that height, as at *E*, leaving the ſpace above it in the Glaſs, void of Quick-ſilver: (But, whether filled by any other imperceptible Fluid, we diſpute not.)

The Reaſon why it ſo ſinks, our Anceſtors have not aſſigned; Becauſe they were not at all aware of this Phænomenon; but thought, that (*ne detur vacuum*) it would remain full, whatever the height of the Tube were.

Some Moderns (with *Des Cartes*) that they might avoid a *Vacuum*, do imagine, that a *Materia ſubtilis* (of which no Senſe can make any diſcovery) piercing the Pores of the Glaſs, ſupplies that place. But, if it will ſo ſupply the place above *E*, and give the Quick-ſilver leave to ſink ſo low; why it might not as well come-in to relieve the reſt, and ſo give it leave to ſink to *A*, I do not find.

Others (with *Linus*) imagine, that the weight of 29 inches of Quick-ſilver doth ſtretch ſome part of its upper ſurface into a ſubtile matter, very thin, yet ſo as to fill that ſeemingly void ſpace; but, becauſe a leſs weight will not ſerve ſo to ſtretch it, it falls no low-

er; which ſtretched matter, like a *Funiculus*, holds up the reſt, *ne detur vacuum*. But, why this Weight ſhould ſtretch ſome very ſmall part of it, ſo prodigiouſly thin, and not ſtretch the reſt at all, rather than give ſome moderate Tenſure to the whole; they do not (that I remember) aſſign any Reaſon.

Others, ſuppoſe this *Funiculus* to be made, not by ſtretching the upper part of the Quick-ſilver; but by ſqueezing out the more ſubtil parts from the whole body of it, which like a vapour fills that ſeemingly void ſpace; but that leſs than ſuch a weight would not ſo ſqueeze it, and therefore it falls no lower. But, why it ſhould ſo fall out, that all Liquors whatever, of never ſo different Texture, ſhould by the ſame weight be thus diſſolvable; and not rather ſome require a greater, ſome a leſſer weight thus to reſolve or ſqueeze them; they aſſign no Reaſon: Yet we find ſo it is, ſince that the lighter the Liquor is, the greater height muſt be allowed, and in ſuch proportion greater, to make up an equivalent weight.

But the cauſe is, *ſay we*, (and it ſeems the moſt ſimple and unforced account,) becauſe the Counter-preſſure of the Air, being equivalent to that of about 29 inches, ſo much it is able to ſuſtain but no more; and juſt ſo much weight it will ſuſtain whatever the Liquor be, whether ſpecifically Lighter or Heavier, and whether of a more Firm or a Looſer texture; and therefore to ſuch a height it ſinks, but no lower.

And had the Ancients been aware of what we find; That the Air hath a poſitive Gravity; and, conſequently, though it be but ſmall in proportion to that of other bodies, yet a great height of Air may countervail a leſſer height of a Heavier Liquor; (like as we ſee that a greater height of Water will countervail a leſſer height of Quick-ſilver:) They would not, I preſume, have troubled themſelves with a *Fuga vacui*; but ſaid roundly, That the weight of the Air at its full height, is equivalent to that of Water at the height of about 34 foot, and of Quickſi-lver, at about 29 inches, and proportionably of other Fluids. And conſequently, when (in the Pump or Syringe) *D* by the *Embolus* or Sucker is defended from the Airs Preſſure, but *A* expoſed to it (in *Fig.* 34.) this Preſſure on *A*, will raiſe, over *B*, ſo much weight of Water, Quick-ſilver, or other Fluid, as is equivalent to that

Preſ-

Preſſure. In the ſame manner as (if *A* and *E* were equally expoſed to the Airs Preſſure) a quantity of Oyl, poured on *A*, would have raiſed a weight of Water or Quick-ſilver equivalent thereunto.

The like account we give of the Syphon. The Preſſure on *A*, (in *Fig.*35.) will raiſe the Fluid to the height of *B*, if not greater than what is before deſcribed; and from thence to *O*, it falls by its own Weight: Yet ſo, that if *O* were higher than *A*, the Airs Preſſure at *O*, would thruſt up *O* to *B* (ſuppoſing the Pipe not ſo big, as that the Air could conveniently paſs by the Liquor into the Pipe,) and it would fall down to *A* by its own Weight. For now *BO* would leſs gravitate than *BA*; while yet the Airs Preſſure would be much the ſame on both.

There is yet a conſiderable Objection to be removed, *viz.* That Air in a cloſed Veſſel, though of no great height, preſſing on *A* the ſurface of the ſtagnant Quick-ſilver, (*Fig.*37.) will ſuſtain as high a Pillar thereof in a cloſed Tube, ſuppoſe *AE*, as if *A* were expoſed to the open Air: Whereas yet the Weight of *AD* within the Veſſel, (defended by the Veſſel from the Preſſure of the incumbent Air,) cannot be of equal Weight as if it had the whole height of the Atmoſphere.

But the Reaſon of this is, from the Airs Spring; which is always equivalent to the Preſſure lying upon it: And conſequently, the Spring of the Air in its ordinary conſtitution with us, muſt be equivalent to the Weight of the incumbent Air. (For, if it were leſs, the Air incumbent would yet preſs it cloſer; if it were more, the Spring would relax it ſelf, by thruſting away what preſſeth it.) Which being ſo; the Air included with ſuch a Spring, muſt therefore preſs with as great a ſtrength as is equivalent to ſuch a Weight. Like as, in other Springs, if *ACB* (in *Fig.*38.) be preſſed by the Weight *D* to ſuch a Tenſure as to bear it; and then, this Spring ſo remaining, the Weight were taken away, and our hand put in the place of it; it would preſs as hard againſt the hand, as before it did to ſuſtain the Weight; that is, with a Force equal to that of the Weight it ſuſtained: And if, thus bowed, it were put in a Veſſel, (in *Fig.* 39.) it would, with

juſt the ſame Force, preſs againſt the ſides of it. And juſt ſo it is in the preſent Caſe; where the Air ſo included doth preſs by its Spring, juſt with the ſame Force as was that of the incumbent Air which gave it this Tenſure.

It is yet the more evident, becauſe if (by the Air-Pump) part of this Air be pumped out, and thereby the reſt leſs compreſſed; the Quick-ſilver in the Tube, (in *Fig.*37.) will ſink from *E* to a lower Station, as to *F* or *G*; and ſo lower and lower, as more and more Air is pumped out, and the Spring thereby relaxed: That is, as the Spring grows weaker, ſo it is leſs able to ſupport the Weight.

And this quite deſtroys the Evaſions but now mentioned; That the ſeeming void ſpace is filled by a thin Subſtance, which can by the Weight of 29 inches of Quick-ſilver, or 34 foot of Water, but not by leſs, be ſtretched to that fineneſs; and that therefore it will ſink to that height, but not lower.

For, by this laſt Experiment, when the Air is included with its ordinary Tenſure, it ſuſtains the Quick-ſilver at the height of 29 inches; as if leſs than that Weight were too little to ſtretch the Quick-ſilver into that ſuppoſed fine ſubſtance: But, when that Air, by pumping, is weakned; it will ſink to 20, 10, 5, yea leſs than 1 inch of height; as if now leſs than the Weight of 1 inch were enough ſo to ſtretch it, as leſs than 29 inches would not do before. Yet is no alteration, all this while, made in the Texture of the Quick-ſilver; but in the Tenſure of the Air onely. 'Tis therefore from this different Tenſure or Spring of the Air, not from any difference in the Quick-ſilver, that it ſtands ſometime at a higher, ſometime at a lower ſtation.

And what hath been thus ſaid of this *Torricellian* Experiment, is eaſily applicable to others of like nature. And it is confeſſed, that, as the notion of *Fuga vacui*, or that of the Airs preſſure, doth ſtand or fall as to this Experiment; ſo muſt it do as to the others alſo. I content my ſelf therefore, to have ſhewed it in this; without expatiating to other particulars.

FINIS.